Received 17 February 2023
Revised 7 May 2023
Accepted 17 June 2023

The impact of the stringency of environmental policy on a firm's financial performance: an empirical study of European automobile manufacturers

Fahimeh R. Chomachaei and Davood Golmohammadi
University of Massachusetts System, Boston, Massachusetts, USA

Abstract

Purpose – The authors investigate the impact of the stringency of environmental policy on the financial performance of European automobile manufacturers. This paper contributes to the debate about the impact of environmental policy on a firm's competitive performance.

Design/methodology/approach – The authors use cross-country sector-level panel data for 71 firms from 18 European countries from 2010 to 2019. The authors apply a fixed-effect model and then, to address the endogeneity issues, the authors use the generalized method of moments (GMM) model. To further examine the validity of the results, the authors use a data-mining modeling approach as a robustness test.

Findings – By considering the dynamic impact of environmental policy and overcoming the endogeneity issues, the results show that the impact of the stringency of environmental policy on a firm's financial performance depends on the time horizon: the stringency of environmental policy has a short-term negative impact but a long-term positive impact on a firm's financial performance.

Research limitations/implications – The authors limited the study to the auto industry in Europe. In addition, future research could consider the impact of environmental policy on other financial performance indicators such as Return on Sales or Return on Equity. Also, it would be interesting to conduct a similar study in the United States or China using a firm-level data set to examine the robustness of the results.

Practical implications – Stringency of environmental policy improves a firm's financial performance in the long term. It is essential for firms and managers to consider the dynamic impacts of environmental policy on their financial performance and adopt a long-term perspective when evaluating the costs and benefits of complying with environmental regulations. The findings help management develop a long-term vision for investment and budget allocation. The results support management's view for strategic decision-making against the common budget argument and challenges for stockholders when it comes to adopting new technologies and planning long-term investment.

Social implications – It is crucial for firms to recognize the broader societal benefits that come with environmental policy. Firms must not only focus on their financial performance but also on their social responsibility to protect the environment and contribute to the greater good. Therefore, firms must take a long-term perspective and recognize the broader societal benefits of environmental policy in order to make informed decisions that support both their financial success and their social responsibility.

Originality/value – This paper contributes to the literature by helping to explain the inconsistent results of studies about the impact of environmental policy on a firm's competitiveness. Using a firm's financial performance as one of the main metrics for competitiveness, this study takes into account both endogeneity and contemporaneity in evaluating the impact of the stringency of environmental policy on a firm's financial performance.

Keywords Environmental policy, Financial performance, Empirical study, Data mining, Neural networks, Automobile industry

Paper type Research paper

The International Journal of Logistics Management
Vol. 35 No. 3, 2024
pp. 736-754

0957-4093
DOI 10.1108/IJLM-02-2023-0067

1. Introduction

There is a growing concern regarding climate change. Climate-neutral supply chains are becoming increasingly important in the global effort to combat climate change. By 2050, the global fleet of private cars will have tripled, increasing CO_2 emissions and average global temperature (United Nations Environment Program, 2016). The manufacturing industry, especially the automobile industry, is a significant contributor to greenhouse gas emissions. Thus, the implementation of climate-neutral supply chains in this industry can play a crucial role in reducing emissions and achieving climate goals. Implementing a climate-neutral supply chain involves reducing emissions across the entire production process, including the sourcing of raw materials, production, transportation and end-of-life disposal.

In recent years, governments and policymakers have implemented various environmental policies to encourage companies to adopt sustainable practices and reduce their carbon footprint. European countries have well taken the importance of climate change for decades. The European Union (EU) Environmental Policy (EP) was introduced in 1973 (European Parliament, 2023). According to the European Commission (EAP, 2020): "Over the past decades the European Union has put in place a broad range of environmental legislation." Many people are concerned that stringent environmental regulations would impose a substantial strain on European firms, limiting their growth and undermining their competitiveness in an increasingly global marketplace. Given current developments in energy and environmental policy, examining the relationship between environmental policy and competitiveness is especially important for Europe.

There is a debate about whether environmental policy may enhance competitiveness by pushing companies to be more productive and efficient with their products and designs; even if those changes enhance productivity and efficiency, there is concern that the changes can add to operations costs and consequently hurt the financial performance of companies (Brännlund and Lundgren, 2010; Ramanathan *et al.*, 2010; Rubashkina *et al.*, 2015; Zhao *et al.*, 2015). A firm's competitive performance is one of the most important concepts in management research. Competitive performance includes financial performance, product market performance and shareholder return (Richard *et al.*, 2009). In this paper, we investigate the impact of environmental policy on the financial performance of firms in the European automobile industry. The automobile industry is one of the key contributors to the national economy, particularly in industrialized countries (Ülengin *et al.*, 2014). A variety of environmental policies target the automobile industry because of its negative impact on the environment it contributes 23% of total energy-related CO2 emissions (Leggett, 2021). The global greenhouse gas emissions attributed to the automobile industry can be classified into two primary categories. The first category is the CO_2 released into the atmosphere as a result of transportation. The IEA report indicates that road vehicles, including cars, trucks, buses, two-wheelers, and three-wheelers, account for about 75% of transportation CO_2 emissions (Leggett, 2021). The second category is the environmental impact of the car-manufacturing process. "Environmental impacts start with mineral extraction and the production of the raw materials that go into the parts of a car" (Greencars.org, 2023). Every component and part of the automobile is associated with some degree of pollution; energy consumption, air pollution, and the release of toxic substances are the primary contributors during the production process. However, the negative impact of the automobile industry on the environment does not end there. During the use of the vehicle, pollutants continue to be emitted into the atmosphere, which contributes to worsening air quality in many cities around the world. Moreover, the disposal of end-of-life vehicles presents a significant challenge, as many of the materials used in automobile construction are nonbiodegradable and can persist in the environment for decades, if not centuries.

Despite these challenges, the automobile industry is making progress in reducing its environmental impact. Many car manufacturers are exploring new technologies, such as electric and hybrid engines, which have the potential to significantly decrease emissions. Efforts are also underway to enhance the recyclability of car parts and reduce waste generated during the production process.

It is evident that the automobile industry has a critical role to play in combating global climate change and minimizing environmental damage. In the coming years, continued efforts to develop cleaner and more sustainable transportation technologies will be essential. Therefore, we study the impact of the stringency of environmental policy on financial performance using cross-country sector-level panel data for 18 European countries between 2010 and 2019. We use a fixed-effect model; to deal with the endogeneity issue, we apply the Generalized method of moments (GMM) model (Ullah *et al.*, 2018; Javeed *et al.*, 2020). Additionally, we implement a robustness test via data-mining tools to further validate our results. We show that the stringency of environmental policy has a negative impact on a firm's financial performance in the short term but has a positive impact in the long term. Our findings help explain the current inconsistent findings in the literature regarding the impact of environmental policy on a firm's competitive performance. Our aim is to summarize the broad statistical relationships that exist between pollution-control expenditures and competitive performance across manufacturers and time.

The rest of the paper proceeds as follows. Section 2 provides background about this subject. Section 3 explains our data and research methodology. Section 4 describes empirical modeling and results. Section 5 addresses the endogeneity concern. Section 6 presents our robustness tests and their results. Section 7 provides further discussion, a summary of contributions and concluding remarks.

2. Theoretical background and hypothesis development

2.1 The relationship between financial performance and competitive performance

One of the most fundamental aspects of management research is a firm's competitive performance, which includes financial performance, product market performance and shareholder return (Richard *et al.*, 2009). Gentry and Shen (2010) define financial performance as how well a firm achieves its economic objectives. Financial performance has been a central focus in management research on firm performance. In order to evaluate financial performance, researchers typically use either accounting-based metrics (such as return on assets [ROA], return on sales [ROS] and return on equity [ROE]) or market-based metrics (such as Tobin's Q and market return) (Hult *et al.*, 2008; Molina-Azorín *et al.*, 2009; Gentry and Shen, 2010). Accounting-based metrics reflect operational efficiency and effectiveness; market-based metrics reflect investors' perceptions rather than the firm's fundamental value (Thaler, 2005). Hutchinson and Gul (2004) reported that accounting-based metrics are best for empirical studies of firm governance because accounting-based metrics can more easily connect management's ability to the firm's value. Therefore, we use accounting-based metrics to investigate the impact of environmental legislation on firms' financial performance.

2.2 The effect of environmental policy on competitiveness

Policymakers have implemented a variety of regulations and policies to reduce the carbon emissions from factories. Policymakers and practitioners debate the effects of environmental regulation on competitiveness (Iraldo *et al.*, 2011) from viewpoints such as financial performance, market-share performance or innovation performance. The fixed costs or variable costs of operations rise as a consequence of implementing the requirements of environmental regulations; these cost increases are likely to negatively affect competitive performance (Jaffe *et al.*, 1995; Brännlund and Lundgren, 2010; Rubashkina *et al.*, 2015; Zhao and Sun, 2016). On the other hand, if the environmental regulations are designed properly, firms will have a greater incentive to enhance efficiency and productivity in order to reduce pollution. This improvement, in turn, leads to cost-cutting product innovation, which eventually offsets the initial cost increase. As a result, environmental regulations may enhance competitiveness (Porter and Van der Linde, 1995; Ramanathan *et al.*, 2010; Zhao *et al.*, 2015). Because of these contradictory ideas, there is an increasing interest in the literature to explore the impact of environmental regulations on competitiveness.

Porter and Van der Linde (1995) hypothesized that the increasing stringency of environmental regulations does not always penalize a firm's competitive performance. Numerous studies have examined the Porter hypothesis. They investigated the impact of different environmental policies on a firm's performance across different industries in several countries. Many scholars confirmed this hypothesis (Molina-Azorín *et al.*, 2009). As an example, Berman and Bui (2001) studied the effect of environmental policy on the financial performance of oil refineries in Los Angeles, California, from 1979 to 1992. They used total factor productivity (TFP) as a proxy for financial performance (TFP indicates how effectively productive inputs are combined to generate gross outputs, Rubashkina *et al.*, 2015). Berman and Bui found that stringency of environmental policy increased a firm's productivity (Berman and Bui, 2001). Javeed *et al.* (2020) investigated the effect of environmental policy on a firm's financial performance in the manufacturing sector of Pakistan's industries. They considered the expenditures on environmental assets that firms usually pay as a proxy for costs of environmental regulations. Also, they used return on assets (ROA) and sustainable growth rate (SGR) as two proxies to measure a firm's financial performance. The results indicated a positive relationship between the stringency of environmental policy and a firm's financial performance.

Contrary to this positive relationship, many studies have found a negative relationship between environmental policy and a firm's competitive performance. For example, Palmer *et al.* (1995) argued against the Porter hypothesis. They found that environmental policy would increase the costs of a firm and reduce its competitiveness. Khanna and Damon (1999) examined the relationship between an Environmental Protection Agency voluntary program and a firm's financial performance in the U.S. chemical industry. They discovered participation in the program had a significant negative impact on the firm's current return on investment but a significant positive impact on the firm's expected long-term profitability. Zhao and Sun (2016) conducted an empirical study to investigate the Porter hypothesis by studying a good sample size of data from 2007 to 2014 selected from pollution-intensive industries designated by the China Securities Regulatory Commission. The researchers considered ROA as a proxy for a firm's financial performance. The results indicated that environmental regulation had an insignificant negative impact on a firm's financial performance.

Molina-Azorín *et al.* (2009) performed a literature review of quantitative studies that investigated the impact of different environmental policies and regulations on financial performance. They identified 32 studies that looked into this effect; only 21 of them found a positive impact of environmental policy on a firm's financial performance. The impact of environmental policy (EP) on a company's financial performance can differ based on the nature of the EP and the industry sector (Iraldo *et al.*, 2011; Dechezleprêtre and Sato, 2017). Table 1 summarizes the related articles in the literature.

Overall, in the literature, there are conflicting views regarding the effects of environmental regulation on competitiveness. We argue that this relationship may not necessarily be linear (positive or negative) as discussed in the literature, and the relationship can change over time.

We argue that the financial performance of a firm is affected by environmental policy in a dynamic manner, with the outcome varying based on the timeframe. In the short term, environmental policy may raise costs for a firm due to expenses incurred in complying with environmental legislation. However, in the long term, strict environmental policy serves as an incentive for a firm to enhance efficiency and productivity in order to minimize pollution. This improvement leads to cost-effective product innovation, which ultimately offsets the initial cost increase and improves financial performance. In summary, environmental policy can

Table 1.
Summaries of related articles

Study	Sample	Environmental policy (EP) variable	Financial performance variable	Major findings
Khanna and Damon (1999)	U.S. manufacturing firms in chemical industry	Participation in voluntary environmental program	Return on investment, Return on sale	Negative and significant impact of EP on financial performance
Berman and Bui (2001)	Los Angeles, U.S. manufacturing firms in the oil- refinery industry	PACE Cost	TFP	Positive impact of EP on financial performance
Ramanathan *et al.* (2010)	Swedish manufacturing sectors	CO_2 tax	Firm's profit	Negative and significant impact of EP on financial performance
Brännlund and Lundgren (2010)	U.K. manufacturing firms SIC codes 10–41	Pollution control expenditures	Growth value added	Positive impact of EP on financial performance
Zhao *et al.* (2015)	China's electrical power, iron, and steel manufacturing	Emission standards	Reductions in production cost, compliance cost	Positive impact of EP on financial performance
Zhao and Sun (2016)	China'a pollution-intensive firms	Intensity of local government's environmental regulation	ROA	Negative insignificant impact of EP on financial performance
Javeed *et al.* (2020)	Pakistan manufacturing firms	environmental asset expenditures	ROA, SGR	Positive impact of EP on financial performance

Source(s): Author's own work

have either a positive impact or a negative impact on a firm's financial performance, depending on the time frame considered. Accordingly, the following hypothesis is proposed:

H1. The relationship between environmental policy and a firm's financial performance is "U" shaped.

3. Research methodology and modeling

We collected data from 2010 to 2019 for all automobile manufacturers and all autoparts production firms in 18 European countries. The countries were selected based on the availability of data on our proxy for environmental policy. To avoid the effect of the COVID-19 pandemic, we did not consider data from the years 2020 to 2022. We considered firms' financial performance to evaluate their competitiveness. We captured the stringency of environmental legislation in the form of the National Expenditure on Environmental Protection (NEEP). Since our data are panel data and we are interested in analyzing the impact of NEEP on financial performance that varies over time, we first apply a fixed-effect model to address the heterogeneity issue (Ullah *et al.*, 2018). Then, we identify the endogeneity in panel data by implementing the Durbin-Wu Hausman test under OLS regression (Schultz *et al.*, 2010). In order to rectify the endogeneity issue, we apply the GMM model (Ullah *et al.*, 2018; Javeed *et al.*, 2020). To further examine the validity of our results, we use a data-mining modeling approach as a robustness test.

3.1 Data

We collected the data from 2010 to 2019 of all auto firms with Standard Industrial Classification (SIC) code 3711 and all autoparts firms with SIC code 3714 in European countries that can be identified in the Compustat database. The detailed information about the list of the countries and the companies can be found in the Appendix. The Compustat database contains annual, worldwide and company-level information such as revenue, cash and assets for companies listed in North America, Europe and Asia. More information about this classification is available on "naics.com." After cleaning the data, the data set contained 572 observations from 17 countries and 80 firms.

3.2 Measures and variables

These are the dependent variables, independent variables, control variables and measures used.

3.2.1 Dependent variable. We use Return on Assets (ROA) as a proxy for measuring a firm's competitive performance from a financial perspective. ROA is calculated as net income divided by total assets; it is used extensively in the literature (Richard *et al.*, 2009; Molina-Azorín *et al.*, 2009; Gentry and Shen, 2010; Li *et al.*, 2017; Javeed *et al.*, 2020).

3.2.2 Independent variable. There are several proxies to measure the stringency of environmental legislation. Galeotti *et al.* (2020) classified them into three types: (1) indicators of effort at pollution abatement, such as Pollution Abatement Costs and Expenditures (PACE) by private firms and the implicit tax rate on energy; (2) composite indicators such as counts of regulations and nongovernmental environmental organizations; and (3) emission-based indicators such as the ratio of predicted CO_2 emissions intensity to actual emissions intensity. The first type of indicator has been used extensively (Aghion *et al.*, 2016; Galeotti *et al.*, 2020). PACE is usually obtained from company surveys; it is at the firm level. However, these indicators face criticism because of measurement errors, the possibility of being influenced by reverse causality issues and the inability to accurately gauge the level of regulatory pressure in the presence of market or behavioral failures (Berman and Bui, 2001; Galeotti *et al.*, 2020). Indicators that assess a government's efforts to control pollution consist of environmental R&D spending, expenses on environmental protection, revenue earned through environmental taxes and the implicit tax rate on energy. Although these indicators are at the national level, they reflect the government's dedication to allocate public funds to support the control of pollution (Galeotti *et al.*, 2020). Because of the aforementioned reasons, several studies have considered the impact of environmental policy at a country level on the performance of firms (Ramanathan *et al.*, 2010; Galeotti *et al.*, 2020). Therefore, as a proxy for the stringency of environmental legislation, we use the National Expenditure on Environmental Protection (NEEP) divided by GDP, which is classified as the first type of indicator. NEEP evaluates the resources consumed by residential units to safeguard the natural environment during a predetermined period of time. "It is the sum of current expenditures on environmental protection (EP) activities and investments for EP activities, including net transfers to the rest of the world" (Eurostat, 2022). NEEP includes expenditures on environmental protection by corporations, the general government, and nonprofit institutions serving households. Corporations' expenditures for environmental protection increased by 62% from 2006 to 2021. Also, approximately 24% of NEEP in the general government sector is spent on environmental research and development and other environmental protection activities, such as general environmental administration and education (The Brussels Times, 2023). NEEP data for European countries are available from EUROSTAT. We divide NEEP by the GDP to control for the economic impact of each country (Eurostat, 2022).

3.2.3 Control variables. Following the literature, we control for a vector of time-variant events at the firm level that may affect a firm's financial performance. We also control for the firm size, which is one of the significant factors impacting a firm's financial performance (Bellamy *et al.*, 2014; Schilling, 2015; Li *et al.*, 2017; Jiang *et al.*, 2018; Javeed *et al.*, 2020). We use total assets divided by GDP as a proxy for the firm size (Jiang *et al.*, 2018; Chu *et al.*, 2019). Also, we consider asset turnover and leverage as other control variables, since these variables have an impact on social and environmental actions (Jennifer Ho and Taylor, 2007; Chu *et al.*, 2019; Javeed *et al.*, 2020).

The list of variables is shown in Table 2. To control for the economic condition of countries on financial performance, our definition of Firm Size is total assets divided by GDP.

Table 3 provides a summary of statistics of the variables used in this study. All firms' characteristics are comparable to those reported in the literature.

4. Modeling and empirical results

Our data set originally contained 572 observations from 80 firms. After we removed the observations with null values in the variables, we had 478 observations from 71 firms. We used log transformation to reduce the variability of the data. Log transformation reduces the impact of outliers and allows us to potentially attain a bell-shaped distribution. Moreover, the range of robustness tests and the examination of error graphs show that the results are more reliable when all variables are log-transformed (Metcalf and Casey, 2016). Log-transformation decreases the skew in the data. We apply log-transformation to all control variables and dependent variables.

Our data set is unbalanced panel data that contain observations about various manufacturers across time. Since the levels that we observe in our individual group (i.e., firm) are not a sample from another large population, we use the fixed-effect method to find the causal effect of NEEP on firms' financial performance (Clark and Linzer, 2015). Also, we control for unobserved heterogeneity (i.e. the likelihood that unmeasured differences among equivalent manufacturers affect their financial performance) by using a fixed-effect method.

Variable	Definition
Dependent Variable	
ROA	Net income divided by total assets
Independent Variable	
NEEP	Annual national expenditure on environmental protection divided by GDP
Control Variables	
Firm size	Total assets divided by GDP
Leverage	Total debt divided by total assets
Asset turnover	Total sales divided by total assets

Source(s): Author's own work

Table 2.
Variable definitions

Variable	Mean	Std. dev	P25	Median	P75
ROA	1.09	0.14	1.10	1.11	1.12
NEEP	1.84	0.45	1.70	1.90	2.10
Firm size	7.00	2.81	4.96	6.41	8.91
Leverage	0.14	0.12	0.05	0.13	0.22
Asset turnover	0.68	0.24	0.54	0.72	0.84

Source(s): Author's own work

Table 3.
Summary statistics

The fixed-effect model investigates the causal relationship between predictors and dependent variables within an entity when there are multiple observations for each entity. In our research, the entity is the firm. Each firm has its characteristics that may or may not influence the dependent variables. In the fixed-effect model, we assume that we control the effect of unobserved characteristics that vary across entities but are indifferent across time. To find the effect of environmental legislation on financial performance, we develop the following regression model.

$$ROA_{it} = \beta_1 NEEP_{t-q} + \beta_2 FirmSize_{it} + \beta_3 Leverage_{it} + \beta_4 AssetTurnover_{it} + c_i + u_{it} + \mu_t \quad (1)$$

where i indexes the firm, t indexes time, c_i captures unobserved time-invariant heterogeneities across the firms, u_{it} captures the error, μ_t is a year effect and q is lagging indicator.

Time effects (μ_t) are included to control for time-dependent determinants of financial performance that are common to all manufacturers, such as changes in policy and changes in economic situation. We use a fixed-effect linear regression model to investigate the impact of NEEP on financial performance.

Prior research demonstrates that the policy variable is most significant for a lag time of zero to two years (Brunnermeier and Cohen, 2003; Johnstone *et al.*, 2017). Therefore, in Equation (1), we test for contemporaneous, zero-year, one-year, and two-year lagged effects of environmental legislation.

To analyze the data, we use STATA version 16.1. To check for the multicollinearity, we use a variance inflation factor (VIF) test for all variables. Since the values of VIF for all variables are below 5, no multicollinearity issues are presented in the results. Each of the VIF scores for our data set met this requirement (mean score of 1.1). Table 4 shows the VIF values of all variables.

Table 5 presents estimation results of the fixed-effect model for the effect of environmental legislation on financial performance. The most important result is that the effect of NEEP on financial performance is negative for $q = 0$, $q = 1$ and $q = 2$. However, it is only statistically significant for a lag equal to zero (i.e., $q = 0$), indicating that the crowding-out effect of environmental policy on a firm's financial performance is evident; this is consistent with the viewpoint of Lanoie *et al.* (2011). A unit increase in NEEP would decrease the ROA by 0.23, all else being equal. However, when lagged environmental policy (i.e. $q = 1, 2$) is introduced, the effect of NEEP on ROA is still negative but insignificant. The results show that the immediate impact of NEEP on financial performance is stronger (p − value < 0.000 for $q = 0$) as opposed to the lagged impact (p − value < 0.37 for $q = 1$; p-value <0.71 for $q = 2$). Moreover, the coefficients associated with control variables used in regressions are generally in line with expectations. The coefficients of firm size and leverage are all nonsignificant, indicating that the impact of these two control variables on financial performance is relatively slight. Compared to the firm's size, the negative effect of leverage is relatively small in terms of economic magnitude. However, the coefficient of asset turnover is positive for lags from zero to two ($q = 0,1,2$), but it is statistically significant only when lag is equal to zero or 1 ($q = 0,1$);

Variable	VIF
NEEP	1.08
Asset	1.19
Leverage	1.01
Asset turnover	1.13
Mean VIF	1.10

Source(s): Author's own work

Table 4. VIF values for variables

Variables	q = 0 Coefficient	Standard error	q = 1 Coefficient	Standard error	q = 2 Coefficient	Standard error
NEEP	−0.230***	0.055	−0.058	0.076	−0.076	0.206
Firm size	0.131	0.143	0.169	0.185	0.139	0.227
Leverage	−0.037	0.142	0.004	0.185	−0.013	0.215
Asset turnover	0.186*	0.110	0.375***	0.130	0.230	0.150
Constant	0.258*	0.147	−0.210	0.187	−0.123	0.265
Number of observations	477	–	404	–	336	–
Number of firms	71	–	69	–	62	–
F test	5.72***	-	2.33**	–	0.68	–
*R*_Squared	0.06	–	0.05	–	0.01	–

Note(s): *(α: 10%) **(α: 5%) *** (α: 1%)
Source(s): Author's own work

Table 5. Regression results for equation (1)

this indicates that the ability of the firm in using its assets to generate revenue has a positive and significant impact on ROA in the short term, which aligns with expectations. Also, when the lag is equal to 2 (q = 2), the model is not overall significant (p -value< 0.6).

In order to check for the presence of serial correlation, we use the Lagrange-Multiplier test for serial correlation; the result shows that serial correlation is not a problem in our data.

5. Endogeneity issue

We check for potential issues of endogeneity in our model. Even with all the control variables included in the model, confounding patterns in financial performance and unmeasured omitted elements that could influence NEEP remain causes of concern (Rubashkina *et al.*, 2015). The endogeneity could cause biased estimation. Endogeneity bias can result in inconsistencies in estimations, which can lead to conclusions and theoretical interpretations that are incorrect (Ullah *et al.*, 2018). It is possible that such bias can even cause coefficients to have an incorrect sign (Ketokivi and McIntosh, 2017; Ullah *et al.*, 2018).

One possibility of endogeneity is omitted bias or simultaneity. Omitted bias happens when the validity of a model is tested without considering all important variables (Schultz *et al.*, 2010; Ullah *et al.*, 2018). The problem of simultaneity arises when two variables affect or cause each other simultaneously and have mutual feedback loops (Ullah *et al.*, 2018). Theoretically, from an econometrics viewpoint, it is understandable that some of the firm's characteristics and NEEP expenditures could be determined endogenously. For instance, a firm with poor performance in one year may decrease its expenditure on NEEP in the following year. Similarly, firms with poor performance are likely to take greater risks in the next few years (Bromiley, 1991). If this source of endogeneity happened, then the error term of endogenous explanatory variables would be correlated with the dependent variable, resulting in a biased and inconsistent result (Greene, 2003). According to the literature, we use the Durbin-Wu-Hasman test to detect the endogeneity of explanatory variables. We follow the common procedures in the literature (Schultz *et al.*, 2010; Ullah *et al.*, 2018). The test results confirm that our modeling suffers from endogeneity issues. To overcome the endogeneity issues, we apply the GMM model. The GMM model is commonly used for panel data; it provides reliable results when various sources of endogeneity are present such as omitted bias, simultaneity and dynamic endogeneity (Wooldridge, 2001). In the GMM model, the lags of the dependent variable are considered as instrument variables to control the endogeneity relationship (Roodman, 2009; Ullah *et al.*, 2018). Researchers usually use two lags of the dependent variable.

They believe that two lags are sufficient for capturing the persistence of the dependent variable (Ullah *et al.*, 2018).

To support our use of the GMM model, research studies have shown that the GMM model is a superior technique to overcome endogeneity in panel data (Schultz *et al.*, 2010; Kneller and Manderson, 2012). For example, Ullah *et al.* (2018) used the GMM model in business research. They investigated the impact of R&D on a firm's financial performance in panel data, and the results showed that the GMM model provided more efficient and consistent estimation compared to the OLS model and the fixed-effect model. Accordingly, to overcome the endogeneity issues, we apply a two-step system GMM model as shown in Equation (2). A two-step GMM, which is a revised version of GMM, can prevent unnecessary data loss (Arellano and Bover, 1995; Roodman, 2009; Ullah *et al.*, 2018).

$$ROA_{it} = \beta_1 ROA_{it-1} + \beta_2 ROA_{it-2} + \beta_3 NEEP_{t-q} + \beta_4 FirmSize_{it} + \beta_5 Leverage_{it} + \beta_6 AssetTurnover_{it} + c_i + u_{it} + \mu_t \quad (2)$$

The definitions for all variables are presented in Table 2. ROA_{it-1} and ROA_{it-2}, respectively, denote the first lag (L1. ROA_{it}) and the second lag (L2. ROA_{it}) of the dependent variable. Since the GMM model controls for endogeneity and incorporates lagged values, the reported results could be significantly different from those reported in the fixed-effect model (Schultz *et al.*, 2010). Table 5 represents the estimation results of the two-step GMM model for the effect of environmental legislation on financial performance. The most notable finding is that the effect of NEEP on financial performance is negative when q = 0, which is consistent with the result in the fixed-effect model; however, it is positive when q = 1 and q = 2. Also, the statistical significance for all three values of q has improved. The results show that NEEP has a negative impact on a firm's financial performance in the short term but a positive impact in the long term. The GMM model is also overall significant for all three values of q. Furthermore, when we used the GMM model, which incorporated the lag values of the previous two years' financial performance, the impact of all explanatory factors changed dramatically in terms of either the sign of the coefficients or the level of significance. For example, the variables leverage and firm size had an insignificant relationship with ROA in the fixed-effect model because of endogeneity. However, they are statistically significant in the GMM model (p-value< 0.0001). By controlling for different types of endogeneity, the GMM model provides more efficient and consistent estimates for the coefficients compared to the fixed-effect model (Ullah *et al.*, 2018). The GMM model provides evidence to support Hypothesis 1. Our model shows that by considering the dynamic nature of environmental policy and overcoming the endogeneity problem, the impact of environmental policy on a firm's financial performance is not linear; this result is different from other studies in the literature (Table 1). Yuan *et al.* (2017) investigated the connection between environmental policy and green-product innovation in China's manufacturing industry. Their results indicated a "U"-shaped relationship between environmental policy and innovation performance. Our research demonstrates a similar relationship between environmental policy and a firm's financial performance.

After implementing the GMM model, we need to apply two post-estimation tests, the Sargen test and the Arellano-Bond test, to determine whether the model is appropriate. The Sargan test is used to check the validity of the model as well as the correct specification of the instrument variables (Bowsher, 2002). If the null hypothesis is rejected, then the model or the instrument variables should be reconstructed. The Arellano-Bond test checks whether the strong exogeneity assumption for lagged variables (instrument variables) is true (Roodman, 2009). The null hypothesis under this test is that the lagged variables are not correlated with the error term in Equation (2). Table 6 shows the results of these two postestimation tests, which prove that the instrument variables and the model we made are correct.

Variables	q = 0 Coefficient	Standard error	q = 1 Coefficient	Standard error	q = 2 Coefficient	Standard error
L1.ROA	0.056***	0.006	0.010***	0.003	0.003	0.003
L2.ROA	0.024***	0.002	−0.011***	0.001	−0.014***	0.001
NEEP	−1.059***	0.029	0.063***	0.010	0.145***	0.017
Firm size	0.810***	0.074	0.777***	0.045	0.786***	0.062
Leverage	0.192***	0.025	0.246***	0.016	0.241***	0.018
Asset turnover	−0.001	0.007	0.196***	0.005	0.200***	0.006
Constant	0.840***	0.049	−0.459***	0.028	−0.547***	0.033
Number of observations	277	–	273	–	273	–
Number of firms	55	–	55	–	55	–
Wald χ^2	2903***	–	2150***	–	1838***	–
Sargan test	33.578	–	34.122	–	33.602	–
Arellano-Bond (AR(1))	−1.16	–	−1.148	–	−1.087	–
Arellano-Bond (AR(2))	0.150	–	0.381	–	0.420	–

Note(s): *(α: 10%) **(α: 5%) *** (α: 1%)
Source(s): Author's own work

Table 6. Regression results for equation (2)

6. Robustness check

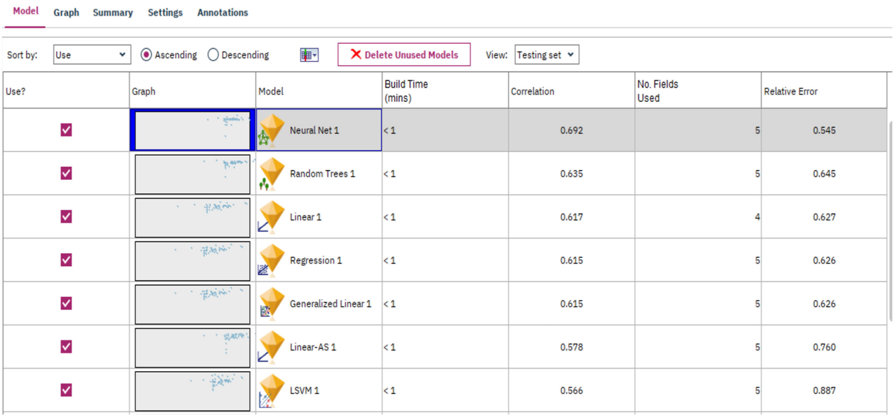
To further examine the validity of our results, we use multiple data-mining models (i.e., neural networks, generalized linear model, linear regression, support vector machine, decision tree, random forest, XGBoost) to check robustness. We use SPSS Modeler (version 18.4) for modeling. Each model is evaluated based on correlation and relative error. The model with the best performance is selected. Next, we conduct a sensitivity analysis to identify important factors; a chart with the predictors ranked indicates the importance of each predictor. More details about the data and modeling are explained below.

6.1 Modeling and results

We split the original data set into two parts: a training data set (75%) and a testing data set (25%). Among twelve data-mining models in SPSS Modeler software, Figure 1 shows the performance of the best six models. The neural networks model shows the best performance; therefore, we focus on neural network modeling in detail.

6.2 Neural networks

Neural network techniques have matured to explore the relationships within large and complex data sets. One of the main advantages of a neural network is that it can handle nonlinear relationships. Thus, assumptions about linearity, independent variables or normality are not needed with neural networks (Thomaidis and Dounias, 2012). In this study, we select the supervised learning technique from the neural network type called multilayer perceptron (MLP). MLP provides ideal performance for classification and regression (Raj and Evangeline, 2020). This neural network model consists of three structures: an input layer, a hidden layer and an output layer. Literature on neural network modeling is extensive and comprehensive, and a detailed discussion of this technique can be easily obtained elsewhere (Golmohammadi *et al.*, 2009, 2020; Parast and Golmohammadi, 2021).



Model Graph Summary Settings Annotations

Sort by: Use | Ascending | Descending | Delete Unused Models | View: Testing set

Use?	Graph	Model	Build Time (mins)	Correlation	No. Fields Used	Relative Error
☑		Neural Net 1	< 1	0.692	5	0.545
☑		Random Trees 1	< 1	0.635	5	0.645
☑		Linear 1	< 1	0.617	4	0.627
☑		Regression 1	< 1	0.615	5	0.626
☑		Generalized Linear 1	< 1	0.615	5	0.626
☑		Linear-AS 1	< 1	0.578	5	0.760
☑		LSVM 1	< 1	0.566	5	0.887

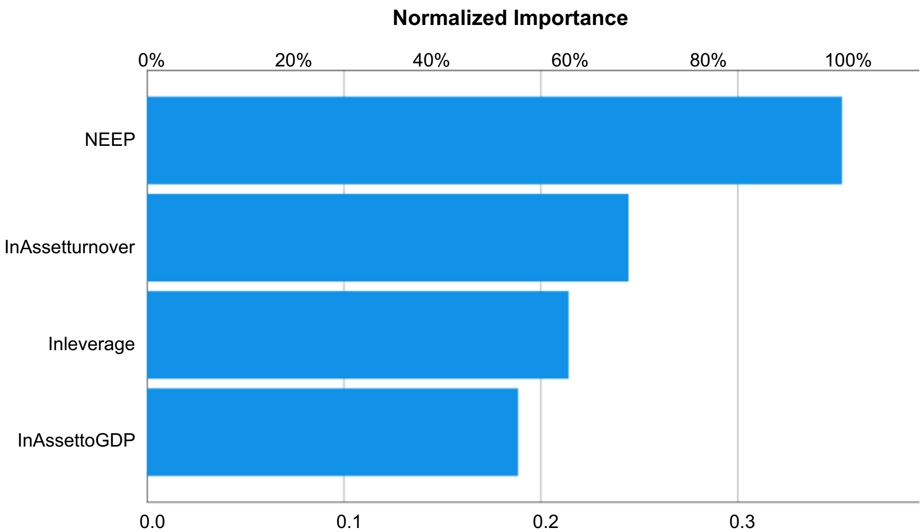
Source(s): Author's own work

Figure 1. Performance comparison of top six data-mining models

The best model performance is based on one hidden layer and the Sigmoid function. For further analysis and to determine which of the input variables has the most significant impact on the output, a sensitivity analysis is performed. Therefore, we can measure the relative importance among the inputs of the NN model to show how the model output varies in response to variations in input (Figure 2) (Schocken and Ariav, 1994; Golmohammadi, 2011). The neural network results confirm our fixed-effect regression analysis. Both models show that NEEP is a significant factor for a firm's financial performance.

7. Discussion and concluding remarks

Using NEEP as a proxy for the stringency of environmental legislation, this paper has provided an empirical investigation to discover the impact of NEEP on firms' financial



Source(s): Author's own work

Figure 2. Sensitivity analysis in the neural network model

performance by using firm-level data from 18 European countries between 2010 and 2019. We allowed the dynamic impact of environmental policy on financial performance to be tested by examining the impact of NEEP by a lag of zero to two years on ROA. The analysis suggests that in the automobile industry in Europe, increasing NEEP has a negative impact on firms' financial performance in the short term but a positive impact in the long term.

This paper makes several main contributions that together show that the relationship between environmental policy and a firm's competitiveness is complex. First, our modeling approach is part of our contribution. We consider the endogeneity problem and rectify it by adopting the GMM model. Only a few articles have addressed this critical issue, which if ignored might lead to biased estimations (Rubashkina *et al.*, 2015; Ullah *et al.*, 2018). Second, we incorporate the contemporaneous relationship between the variables into the model. Third, we capture the stringency of environmental regulation in terms of National Expenditure on Environmental Protection (NEEP). This is different from most studies that consider the Environmental Production Expenditure survey as a proxy for the stringency of environmental policy. The Environmental Production Expenditure survey was conducted irregularly until 2007, so using this as a proxy will reduce somewhat the size and scope of the study (Kneller and Manderson, 2012); we solve this issue by using NEEP. Furthermore, our paper contributes to the debate about the impact of environmental policy on a firm's performance. Our study reveals that by considering the dynamic impact of environmental policy and overcoming the endogeneity issue, environmental policy has either a negative impact or a positive impact on a firm's financial performance, depending on the time horizon. Thus, by considering the endogeneity and contemporaneous aspects of the environmental policy and a firm's financial performance, it is possible to resolve the apparently inconsistent results in the empirical literature.

According to our findings, in the short term, a stringent environmental policy has a crowding-out effect on a firm's financial performance, indicating that financial performance in the auto industry in Europe is typically negatively affected by the compliance cost of environmental policy because it may correspond to a direct increase in costs. The firm must pay for certain factors of operations and production required by environmental legislation. New investments in machinery, technology and training are part of direct and evident costs and challenges for companies to cope with. Such costs and changes put pressure on companies in financial terms, but there is another level of challenge for automobile companies. They rely heavily on their supply chain networks. This means that all changes to adopt new environmental policies impact the suppliers as well. Many of the suppliers may face financial hardship beyond their capacity and resources to cope with new technologies or equipment. Many suppliers may not be able to heavily invest in new technologies unless they increase the prices of their products. A very recent empirical study in the auto industry in China found that strict environmental regulations have a negative impact on productivity by increasing operations costs and reducing industry profits (Liang and Fu, 2021). However, in the long term, the stringency of the environmental policy increases a firm's incentive to improve efficiency and productivity to reduce pollution. This improvement, in turn, leads to cost-cutting product innovation, which eventually compensates for the initial cost increase. Environmental policies are seen as a net positive force that encourages private businesses and the economy as a whole to become more competitive in global markets, in addition to having benign effects on international competitiveness (Jaffe *et al.*, 1995). Therefore, stringency of environmental policy improves a firm's financial performance in the long term. It is essential for firms and managers to consider the dynamic impacts of environmental policy on their financial performance and adopt a long-term perspective when evaluating the costs and benefits of complying with environmental regulations. Our findings help management develop a long-term vision for investment and budget allocation. The results support management's view for strategic decision-making against the common budget argument and challenges for stockholders when it comes to adopting new technologies and planning long-term investment.

Our analysis shows that, when one allows contemporaneous effects to occur and solves the endogeneity issue, the impact of environmental policy on financial performance could become less detrimental. Our finding makes several contributions to policy implications. A short-term negative relationship between the stringency of environmental policy and financial performance asserts that firms trying to improve environmental performance divert resources and action plans away from their core business operations, resulting in reduced profits. Managers face challenges to improve both the environment and their competitiveness. Therefore, it is crucial for management and senior leadership to embrace all effective process- and operations-improvement tools and techniques (e.g., Lean and Six Sigma, integrated information systems) and potential technological improvements to make the system and operations very efficient and cost-competitive. Such managerial and strategic approaches can create some level of leverage for the firms while they need to adapt to new environmental policies. These policies can have a detrimental impact on financial performance if efficient resource management is not one of the main focuses for leadership. To follow this path, a benchmarking analysis should be carried out relative to comparable firms from the standpoint of the business model, resources, and strategies. The role of training for management and employees is crucial, especially for large-size companies or complex businesses with several decision makers in the process. Well-trained and empowered employees and managers are capable of addressing complicated situations and operations challenges. All these types of practices can make firms ready to embrace these environmental policies while minimizing the financial and operations challenges. Moreover, it is crucial for firms to recognize the broader societal benefits that come with environmental policy. Firms must not only focus on their financial performance but also on their social responsibility to protect the environment and contribute to the greater good. Therefore, firms must take a long-term perspective and recognize the broader societal benefits of environmental policy in order to make informed decisions that support both their financial success and their social responsibility.

We limited our study to the auto industry in Europe. In addition, future research could consider the impact of environmental policy on other financial performance indicators such as Return on Sales or Return on Equity. Also, it would be interesting to conduct a similar study in the United States or China using a firm-level data set to examine the robustness of our results.

References

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R. and Van Reenen, J. (2016), "Carbon taxes, path dependency, and directed technical change: evidence from the auto industry", *Journal of Political Economy*, Vol. 124, pp. 1-51.

Arellano, M. and Bover, O. (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68, pp. 29-51.

Bellamy, M.A., Ghosh, S. and Hora, M. (2014), "The influence of supply network structure on firm innovation", *Journal of Operations Management*, Vol. 32, pp. 357-373.

Berman, E. and Bui, L.T.M. (2001), "Environmental regulation and productivity: evidence from oil refineries", *Review of Economics and Statistics*, Vol. 83 No. 3, pp. 498-510.

Bowsher, C.G. (2002), "On testing overidentifying restrictions in dynamic panel data models", *Economics Letters*, Vol. 77, pp. 211-220.

Brännlund, R. and Lundgren, T. (2010), "Environmental policy and profitability: evidence from Swedish industry", *Environmental Economics and Policy Studies*, Vol. 12, pp. 59-78.

Bromiley, P. (1991), "Testing a causal model of corporate risk taking and performance", *Academy of Management Journal*, Vol. 34, pp. 37-59.

Brunnermeier, S.B. and Cohen, M.A. (2003), "Determinants of environmental innovation in US manufacturing industries", *Journal of Environmental Economics and Management*, Vol. 45, pp. 278-293.

Chu, Y., Tian, X. and Wang, W. (2019), "Corporate innovation along the supply chain", *Management Science*, Vol. 65, pp. 2445-2466.

Clark, T.S. and Linzer, D.A. (2015), "Should I use fixed or random effects?", *Political Science Research and Methods*, Vol. 3, pp. 399-408.

Dechezleprêtre, A. and Sato, M. (2017), "The impacts of environmental regulations on competitiveness", *Review of Environmental Economics and Policy*, Vol. 11 No. 2, pp. 181-360.

EAP (2020), available at: https://ec.europa.eu/environment/action-programme/

European Parliament (2023), available at: https://www.europarl.europa.eu/factsheets/en/sheet/71/environment-policy-general-principles-and-basic-framework

Eurostat (2022), available at: https://ec.europa.eu/eurostat

Galeotti, M., Salini, S. and Verdolini, E. (2020), "Measuring environmental policy stringency: approaches, validity, and impact on environmental innovation and energy efficiency", *Energy Policy*, Vol. 136, 111052.

Gentry, R.J. and Shen, W. (2010), "The relationship between accounting and market measures of firm financial performance: how strong is it?", *Journal of Managerial Issues*, Vol. 22 No. 4, pp. 514-530.

Golmohammadi, D. (2011), "Neural network application for fuzzy multi-criteria decision making problems", *International Journal of Production Economics*, Vol. 131 No. 2, pp. 490-504.

Golmohammadi, D., Creese, R.C. and Valian, H. (2009), "Neural network application for supplier selection", *International Journal of Product Development*, Vol. 8, pp. 252-275.

Golmohammadi, D., Parast, M.M. and Sanders, N. (2020), "The impact of service failures on firm profitability: integrating machine learning and statistical modeling", *IEEE Transactions on Engineering Management*, Vol. 69, pp. 3038-3052.

Greencars.org (2023), available at: https://greenercars.org/why-buy-green/automobiles-environment

Greene, W.H. (2003), *Econometric Analysis*, Vol. 16, Prentice Hall, NJ.

Hult, G.T.M., Ketchen, D.J., Griffith, D.A., Chabowski, B.R., Hamman, M.K., Dykes, B.J., Pollitte, W.A. and Cavusgil, S.T. (2008), "An assessment of the measurement of performance in international business research", *Journal of International Business Studies*, Vol. 39, pp. 1064-1080.

Hutchinson, M. and Gul, F.A. (2004), "Investment opportunity set, corporate governance practices and firm performance", *Journal of Corporate Finance*, Vol. 10, pp. 595-614.

Iraldo, F., Testa, F., Melis, M. and Frey, M. (2011), "A literature review on the links between environmental regulation and competitiveness: environmental regulation and competitiveness", *Environmental Policy and Governance*, Vol. 21, pp. 210-222, doi: 10.1002/eet.568.

Jaffe, A.B., Peterson, S.R., Portney, P.R. and Stavins, R.N. (1995), "Environmental regulation and the competitiveness of U.S. Manufacturing: what does the evidence tell us?", *Journal of Economic Literature*, Vol. 33, pp. 132-163.

Javeed, S.A., Latief, R. and Lefen, L. (2020), "An analysis of relationship between environmental regulations and firm performance with moderating effects of product market competition: empirical evidence from Pakistan", *Journal of Cleaner Production*, Vol. 254, 120197, doi: 10.1016/j.jclepro.2020.120197.

Jennifer Ho, L.-C. and Taylor, M.E. (2007), "An empirical analysis of triple bottom-line reporting and its determinants: evidence from the United States and Japan", *Journal of International*

Financial Management and Accounting, Vol. 18, pp. 123-150, doi: 10.1111/j.1467-646X.2007.01010.x.

Jiang, Z., Wang, Z. and Li, Z. (2018), "The effect of mandatory environmental regulation on innovation performance: evidence from China", *Journal of Cleaner Production*, Vol. 203, pp. 482-491, doi: 10.1016/j.jclepro.2018.08.078.

Johnstone, N., Haščič, I. and Popp, D. (2017), "Renewable energy policies and technological innovation: evidence based on patent counts", *Environmental and Resource Economics*, Vol. 68, pp. 441-444, doi: 10.1007/s10640-017-0176-x.

Ketokivi, M. and McIntosh, C.N. (2017), "Addressing the endogeneity dilemma in operations management research: theoretical, empirical, and pragmatic considerations", *Journal of Operations Management*, Vol. 52, pp. 1-14, doi: 10.1016/j.jom.2017.05.001.

Khanna, M. and Damon, L.A. (1999), "Epa's voluntary 33/50 program: impact on toxic releases and economic performance of firms", *Journal of Environmental Economics and Management*, Vol. 37 No. 1, pp. 1-25.

Kneller, R. and Manderson, E. (2012), "Environmental regulations and innovation activity in UK manufacturing industries", *Resource and Energy Economics*, Vol. 34, pp. 211-235, doi: 10.1016/j.reseneeco.2011.12.001.

Lanoie, P., Laurent-Lucchetti, J., Johnstone, N. and Ambec, S. (2011), "Environmental policy, innovation and performance: new insights on the porter hypothesis", *Journal of Economics and Management Strategy*, Vol. 20, pp. 803-842, doi: 10.1111/j.1530-9134.2011.00301.x.

Leggett, D. (2021), "Climate change and the automotive sector", available at: https://www.just-auto.com/analysis/cop26-climate-change-and-the-automotive-sector-1/#::text=By

Li, D., Cao, C., Zhang, L., Chen, X., Ren, S. and Zhao, Y. (2017), "Effects of corporate environmental responsibility on financial performance: the moderating role of government regulation and organizational slack", *Journal of Cleaner Production*, Vol. 166, pp. 1323-1334, doi: 10.1016/j.jclepro.2017.08.129.

Liang, X. and Fu, J. (2021), "Environmental improvement or industry enhancement? A case study on the impact of environmental regulations on Chinese automobile industry", *Regional Sustainability*, Vol. 2 No. 3, pp. 256-263.

Metcalf, L. and Casey, W. (2016), *Cybersecurity and Applied Mathematics*, Syngress, Amsterdam, Boston.

Molina-Azorín, J.F., Claver-Cortés, E., López-Gamero, M.D. and Tarí, J.J. (2009), "Green management and financial performance: a literature review", *Manag. Decis.*, Vol. 47, pp. 1080-1100, doi: 10.1108/00251740910978313.

Palmer, K., Oates, W.E. and Portney, P.R. (1995), "Tightening environmental standards: the benefit-cost or the no-cost paradigm?", *Journal of Economic Perspectives*, Vol. 9 No. 4, pp. 119-132.

Parast, M.M. and Golmohammadi, D. (2021), "Operational slack, service disruptions, and service quality: empirical evidence from the US airline industry", *Computers and Industrial Engineering*, Vol. 161, 107654, doi: 10.1016/j.cie.2021.107654.

Porter, M.E. and Van der Linde, C. (1995), "Green and competitive: ending the stalemate", *Harvard Business Review*, Vol. 73 No. 5, pp. 120-134, September–October 1995.

Raj, P. and Evangeline, P. (2020), *The Digital Twin Paradigm for Smarter Systems and Environments: The Industry Use Cases*, Elsevier Academic Press, Cambridge, MA.

Ramanathan, R., Black, A., Nath, P. and Muyldermans, L. (2010), "Impact of environmental regulations on innovation and performance in the UK industrial sector", *Management Decision*, Vol. 48, pp. 1493-1513, doi: 10.1108/00251741011090298.

Richard, P.J., Devinney, T.M., Yip, G.S. and Johnson, G. (2009), "Measuring organizational performance: towards methodological best practice", *Journal of Management*, Vol. 35, pp. 718-804, doi: 10.1177/0149206308330560.

Roodman, D. (2009), "How to do Xtabond2: an introduction to difference and system GMM in stata", *The Stata Journal: Promoting communications on statistics and Stata*, Vol. 9, pp. 86-136, doi: 10.1177/1536867X0900900106.

Rubashkina, Y., Galeotti, M. and Verdolini, E. (2015), "Environmental regulation and competitiveness: empirical evidence on the Porter Hypothesis from European manufacturing sectors", *Energy Policy*, Vol. 83, pp. 288-300, doi: 10.1016/j.enpol.2015.02.014.

Schilling, M.A. (2015), "Technology shocks, technological collaboration, and innovation outcomes", *Organization Science*, Vol. 26, pp. 668-686, doi: 10.1287/orsc.2015.0970.

Schocken, S. and Ariav, G. (1994), "Neural networks for decision support", *Decision Support Systems*, Vol. 11, pp. 393-414, doi: 10.1016/0167-9236(94)90015-9.

Schultz, E.L., Tan, D.T. and Walsh, K.D. (2010), "Endogeneity and the corporate governance - performance relation", *Australian Journal of Management*, Vol. 35, pp. 145-163, doi: 10.1177/0312896210370079.

Thaler, R.H. (2005), *Advances in Behavioral Finance*, Russell Sage Foundation, New York.

The Brussels Times (2023), EU environmental protection spending reaches new highs [WWW Document], available at: https://www.brusselstimes.com/237681/eu-environmental-protection-spending-reaches-new-highs (accessed 2 April 2023).

Thomaidis, N.S. and Dounias, G.D. (2012), "A comparison of statistical tests for the adequacy of a neural network regression model", *Quantitative Finance*, Vol. 12, pp. 437-449, doi: 10.1080/14697680903426573.

Ülengin, F., Önsel, S., Aktas, E., Kabak, Ö. and Özaydın, Ö. (2014), "A decision support methodology to enhance the competitiveness of the Turkish automotive industry", *European Journal of Operational Research*, Vol. 234 No. 3, pp. 789-801.

Ullah, S., Akhtar, P. and Zaefarian, G. (2018), "Dealing with endogeneity bias: the generalized method of moments (GMM) for panel data", *Indutrial Marketing Management*, Vol. 71, pp. 69-78, doi: 10.1016/j.indmarman.2017.11.010.

UN Environment Programme (2016), Share the Road Global outlook on walking and cycling, available at: www.unep.org/resources/report/share-road-global-outlook-walking-and-cycling

Wooldridge, J.M. (2001), "Applications of generalized method of moments estimation", *The Journal of Economic Perspectives*, Vol. 15, pp. 87-100, doi: 10.1257/jep.15.4.87.

Yuan, B., Ren, S. and Chen, X. (2017), "Can environmental regulation promote the coordinated development of economy and environment in China's manufacturing industry?–A panel data analysis of 28 sub-sectors", *Journal of Cleaner Production*, Vol. 149, pp. 11-24.

Zhao, X. and Sun, B. (2016), "The influence of Chinese environmental regulation on corporation innovation and competitiveness", *Journal of Cleaner Production*, Vol. 112, pp. 1528-1536, doi: 10.1016/j.jclepro.2015.05.029.

Zhao, X., Zhao, Y., Zeng, S. and Zhang, S. (2015), "Corporate behavior and competitiveness: impact of environmental regulation on Chinese firms", *Journal of Cleaner Production*, Vol. 86, pp. 311-322, doi: 10.1016/j.jclepro.2014.08.074.

Appendix

Country	Company name
Austria	Miba AG
Austria	Rosenbauer International AG, Leonding
Austria	Wp Ag
Bulgaria	Balkancar-Zaria JSC
Bulgaria	MS Hydraulic AD
Denmark	Scandinavian Brake Systems A/S (Sbs)
France	Akwel
France	Montupet SA
France	Navya SA
France	P.G.O. Automobiles, St Christol Les Ales
France	Renault SA
France	Valeo SE
Germany	Audi AG (Vormals Audi-Nsu Auto Union AG), Ingolstadt
Germany	Bayerische Motoren Werke AG
Germany	Continental AG
Germany	HELLA GmbH & Co. KGaA
Germany	Hwa AG
Germany	JJ Auto AG
Germany	JOST Werke AG
Germany	Man SE
Germany	Mercedes-Benz Group AG
Germany	Porsche Automobil Holding SE
Germany	Schaeffler AG
Germany	SHW AG
Germany	STS Group AG
Germany	Veritas AG
Germany	Volkswagen AG
Germany	W.E.T. Automotive Systems AG, Odelzhausen
Germany	Williams Grand Prix Holdings PLC
Hungary	Raba Jarmuipari Holdings
Italy	Brembo SPA
Italy	Carraro SPA, Campodarsego (PD)
Italy	Cogeme Set SPA
Italy	Ferrari NV
Italy	Landi Renzo SPA
Italy	Modelleria Brambilla S.p.A
Italy	Pininfarina SPA, Torino
Italy	Sogefi SPA, Mantovana
Luxembourg	Automotive Components Europe SA
Luxembourg	Stabilus SA
Luxembourg	Westa ISIC SA
Netherlands	Kendrion NV, Zeist
Norway	Kongsberg Automotive ASA
Poland	AC SA
Poland	Arrinera SA
Poland	Inter Groclin Auto S.A., Wolsztyn
Poland	OZE Capital SA
Poland	ZM Henryk Kania SA
Portugal	Toyota Caetano Portugal SA
Romania	Altur SA
Romania	Compa SA

(*continued*)

Table A1. List of the countries and the firms

Country	Company name
Romania	Electroprecizia SA Sacele
Romania	Uamt S.A., Oradea
Slovenia	Letrika d.d
Spain	Cie Automotive SA, Azkoitia
Spain	Gestamp Automocion SA
Sweden	Haldex AB
Sweden	Nilsson Special Vehicles AB
Sweden	Scania AB
Sweden	Trention AB
Sweden	VA Automotive i Hassleholm AB
Sweden	Vbg AB
Sweden	Volvo AB
United Kingdom	Autins Group PLC
United Kingdom	GKN PLC
United Kingdom	Journeo plc
United Kingdom	Manganese Bronze Holdings PLC
United Kingdom	Nexteer Automotive Group Ltd
United Kingdom	TI Fluid Systems plc
United Kingdom	Torotrak PLC
United Kingdom	Wheelsure Holdings Plc

Table A1.

Source(s): Author's own work

Corresponding author
Davood Golmohammadi can be contacted at: davood.golmohammadi@umb.edu